Technology Validation: Fuel Cell Bus Evaluations

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Project ID#
TVP2

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Project Start FY03
- First generation FCB complete in FY08
- Second generation FCBs begin 2nd Qtr 2008

Barriers

A. Lack of fuel cell vehicle performance and durability data

B. Lack of H_2 fueling infrastructure performance and availability data

D. Maintenance and training facilities

Budget

- FY 2008: $288K
- FY 2007: $288K
- FY 2006: $288K

Partners

- Fleets: Operational data, fleet experience
- Manufacturers: Vehicle specs, data and review
- Fuel Providers: Fueling data and review

Objectives

- Overall: Validate fuel cell and hydrogen technologies in transit applications
  - Show progress of the technology toward commercialization
  - Provide “lessons learned” on implementing next generation fuel cell systems in transit operations
  - Harmonize data collection efforts with other fuel cell bus demonstrations worldwide (in coordination with FTA and other U.S. and international partners)
- 2008
  - Complete update reports AC Transit and SunLine
  - Begin data collection and analysis for first cold climate site: **CT**TRANSIT
  - Summary of FCB experience and analysis of status

Milestones

- Begin data collection on cold climate sites
  – Hartford, CT: FY07
- Complete evaluations of 1st generation FCBs:
  - Santa Clara VTA: completed FY07
  - AC Transit: FY08
  - SunLine: FY08
  - CTTRANSIT: FY09
- Begin evaluations of 2nd generation FCBs – 2nd Qtr: FY08

Evaluation Approach

Two levels of data collected

- Non-sensitive data
  - Follows existing protocol
  - Data collected mainly from fleet
  - Results are made public after project team review
- Proprietary data
  - Collected from manufacturer
  - Protected in Secure Data Center at NREL
  - Only aggregate data products made public

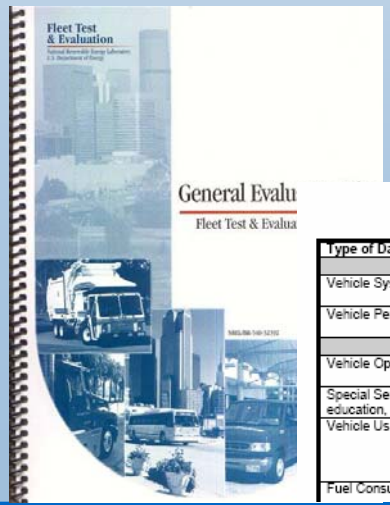
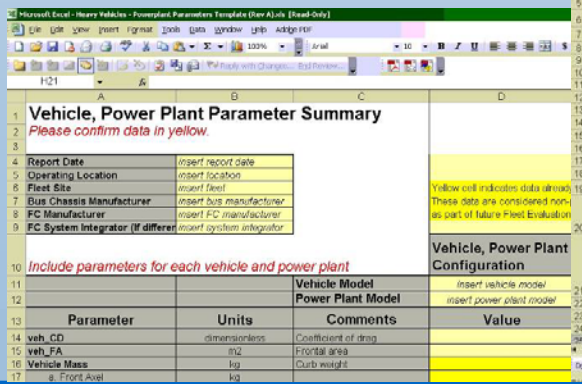
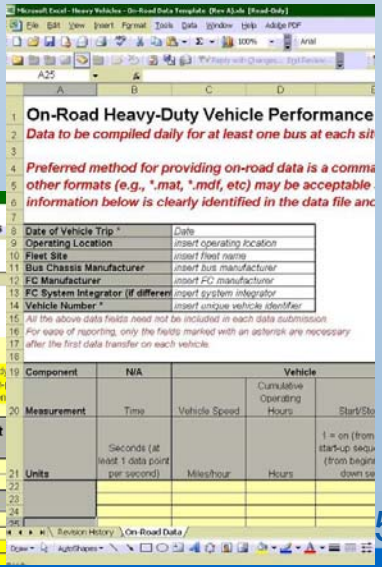


Table 1. Data Collection Items

Type of Data	Frequency Recorded	Data Items
Vehicle Specification and Performance Expectations		
Vehicle System Descriptions	Start of data collection and changes as needed	Data items shown in Appendix C
Vehicle Performance Expectations	Start of data collection and changes as needed	Criteria and testing results for performance expectations
Vehicle Operation		
Vehicle Operating Cycle	Start of data collection and changes as needed	General description of daily use of vehicles
Special Service (Press events, public education, etc.)	Each time vehicle is used for atypical service	Description of event, time out of service.
Vehicle Usage in Service	At each time usage is measured	Odometer reading; hours of vehicle and fuel cell operation
		Daily vehicle assignment
		GPS data (if needed)
Fuel Consumption	Each time a vehicle is fueled	Amount of fuel





Evaluation of Hydrogen and Fuel Cell Buses in Five Fleets

Santa Clara VTA, San Jose, CA - **completed**

Ballard, Gillig: non- hybrid FCB

SunLine, Thousand Palms, CA

UTC Power, ISE Corp: hybrid FCB

ISE Corp: hybrid H_2 ICE

AC Transit, Oakland, CA

UTC Power, ISE Corp: hybrid FCB

CTTRANSIT, Hartford, CT

UTC Power, ISE Corp: hybrid FCB

Hickam AFB, Honolulu, HI

Hydrogenics, Enova: hybrid system

Comparison of Hydrogen and Fuel Cell Buses to Conventional Technology

Targets for assessing the progress toward commercialization

- Performance characteristics
- Bus use
- Fuel economy
- Availability
- Reliability - miles between road call (MBRC)
- Cost - capital, fueling, and maintenance

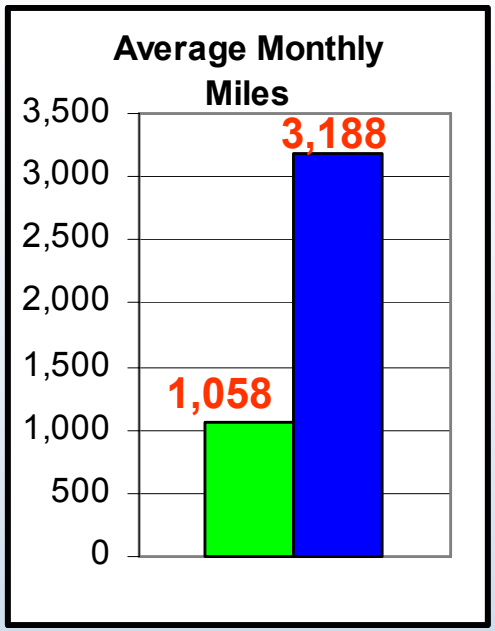
Fleet Data Summary: AC Transit

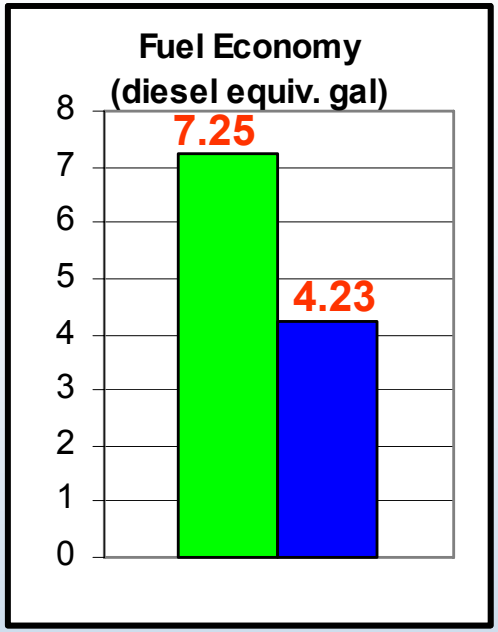
Fuel Cell Bus (hybrid system)

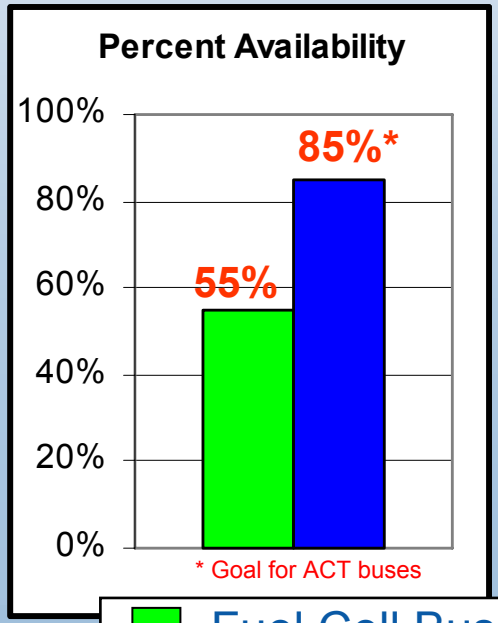
- 24 months operation of 3 FCBs
- Total miles: 82,066
- Total FC system hours: 7,814

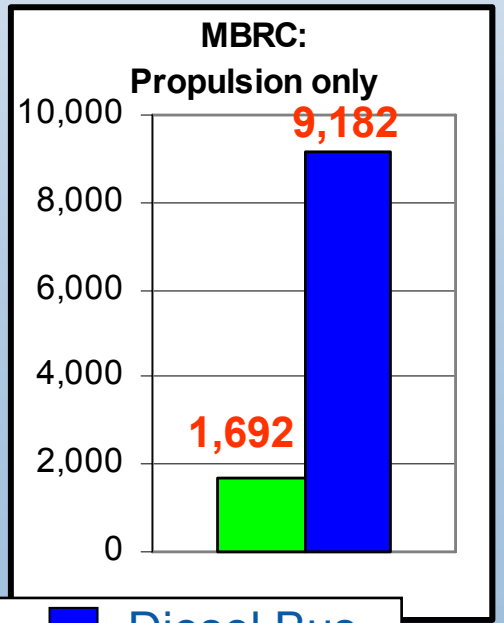
Diesel Bus (baseline)

- 24 months operation of 6 diesel buses
- Total miles: 459,096





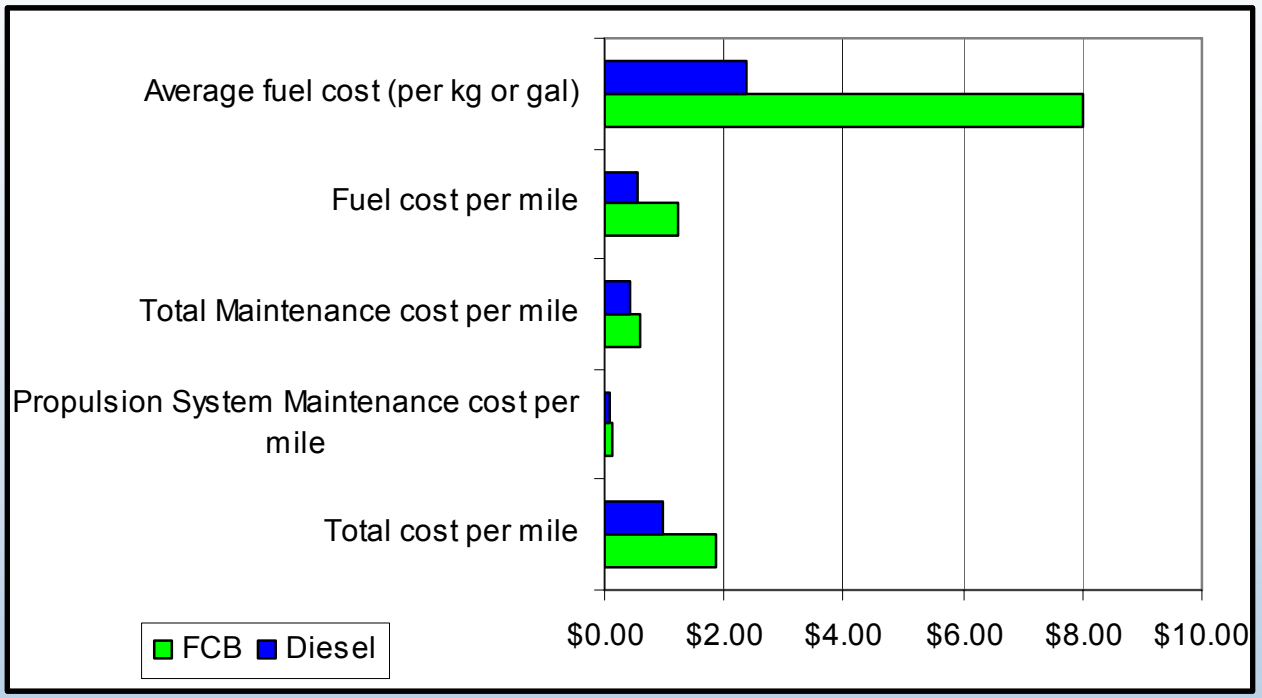


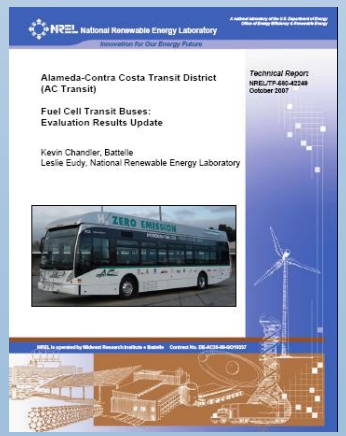


Fuel Cell Bus Diesel Bus

Fleet Data Summary: AC Transit

Summary of Costs





* Warranty data is not included in calculations. Manufacturer staff are conducting most of the system repairs. Costs are expected to increase as fleet takes over these tasks.

Update Report Published 9/07
Available online at www.nrel.gov/hydrogen/pdfs/42249.pdf

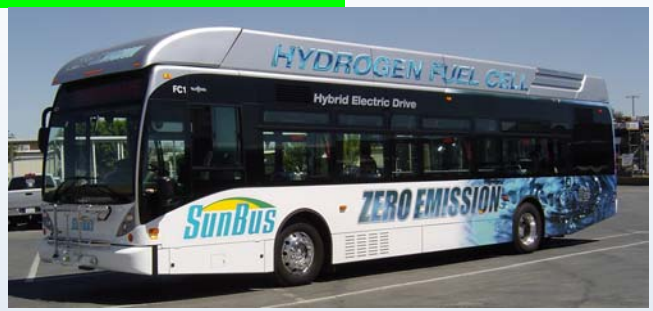
Evaluation Status

- Complete for current generation buses
- Final data report planned for spring
- Data collection will continue under FTA funding (Accelerated testing of current generation)
- Next generation buses arrive 2009 (planned DOE evaluation)

Fleet Data Summary: SunLine

Fuel Cell Bus (hybrid system)

- 27 months operation of 1 FCB
- Total miles: 50,931
- Total FC system hours: 3,918

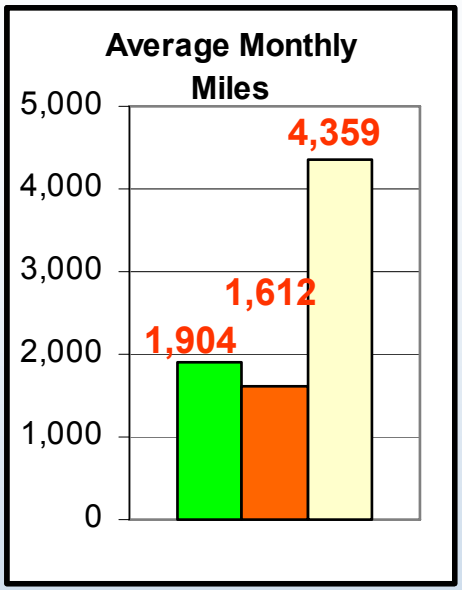


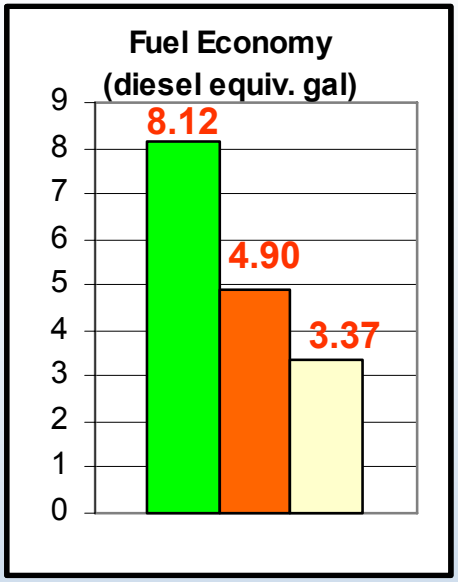
HHICE Bus

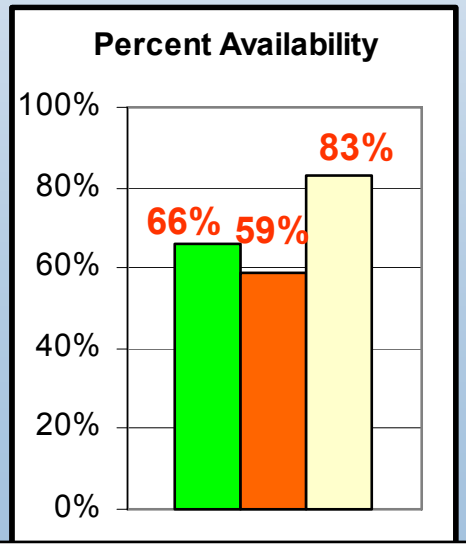
- 27 months operation of 1 HHICE bus
- Total miles: 44,442

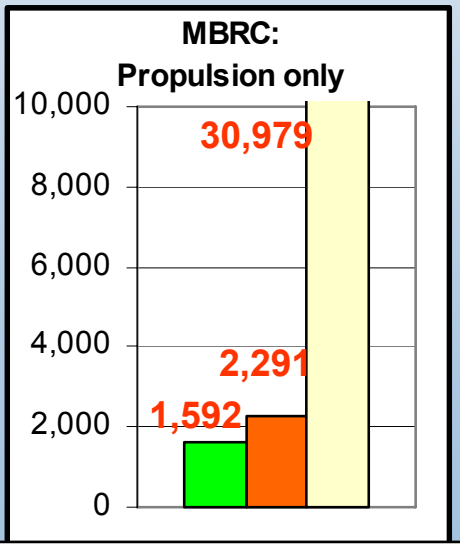
CNG Bus

- 21 months operation of 5 CNG buses
- Total miles: 457,654







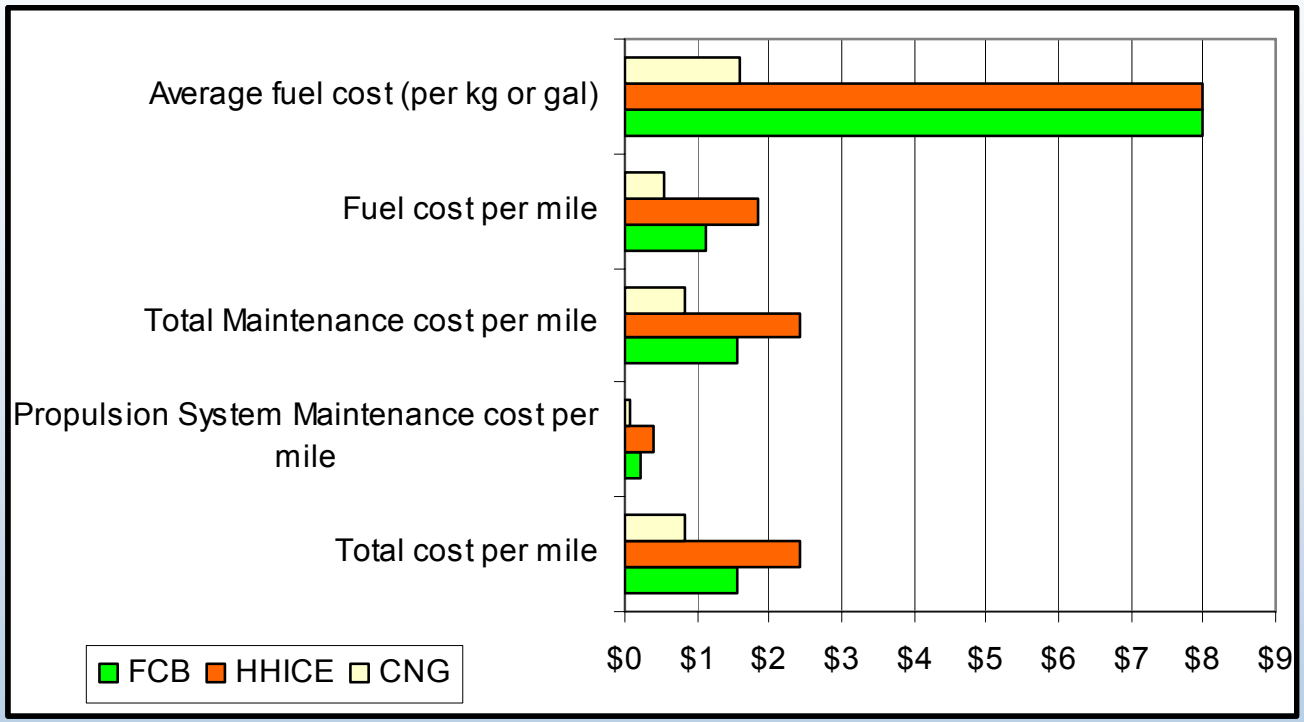


Fuel Cell Bus | HHICE bus | CNG Bus

*HHICE – hybrid H_2 internal combustion engine

Fleet Data Summary: SunLine

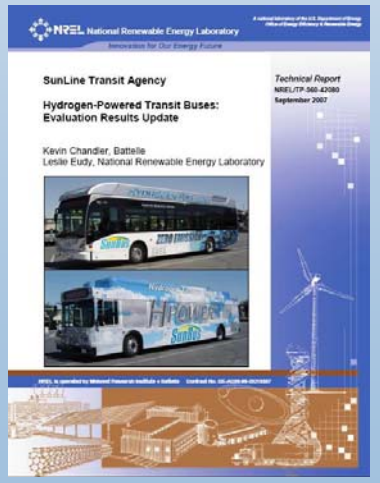
Summary of Costs*



* Warranty data is not included in calculations. Manufacturer staff are conducting most of the system repairs. Costs are expected to increase as fleet takes over these tasks.

Evaluation Status

- Data collection on current gen design nearly complete – final report in summer
- Begin data collection on bus with new design FC



Update report published 9/07
Available online at www.nrel.gov/hydrogen/pdfs/42080.pdf

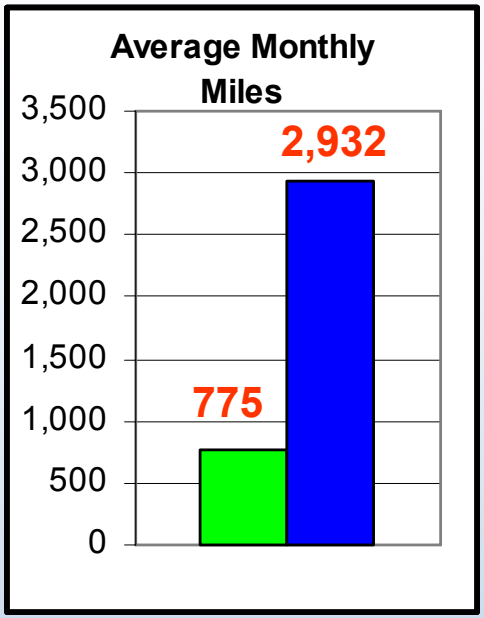
Fleet Data Summary: CTTRANSIT

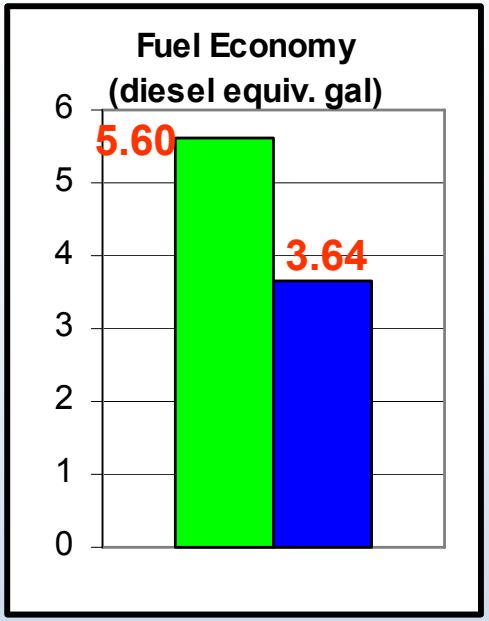
Fuel Cell Bus (hybrid system)

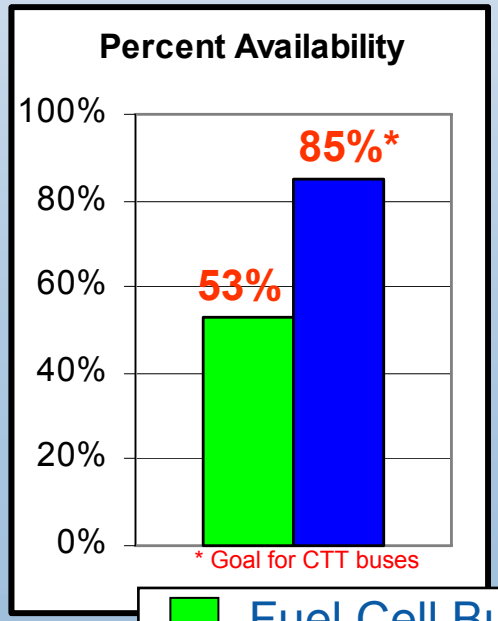
- 12 months operation of 1 FCB
- Total miles: 9,298
- Total FC system hours: 1,596

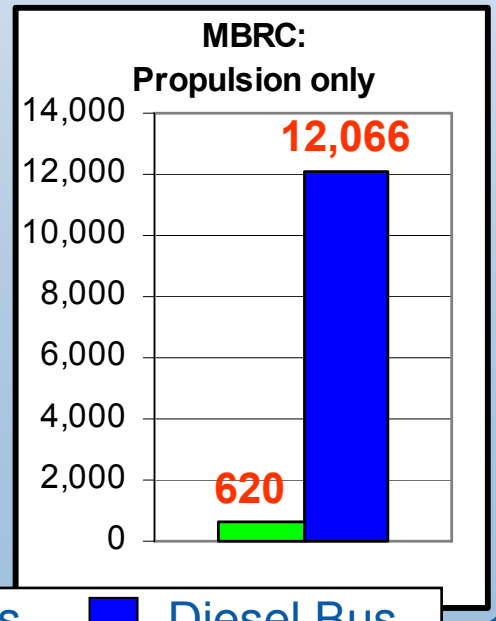
Diesel Bus (baseline)

- 8 months operation of 3 diesel buses
- Total miles: 70,236





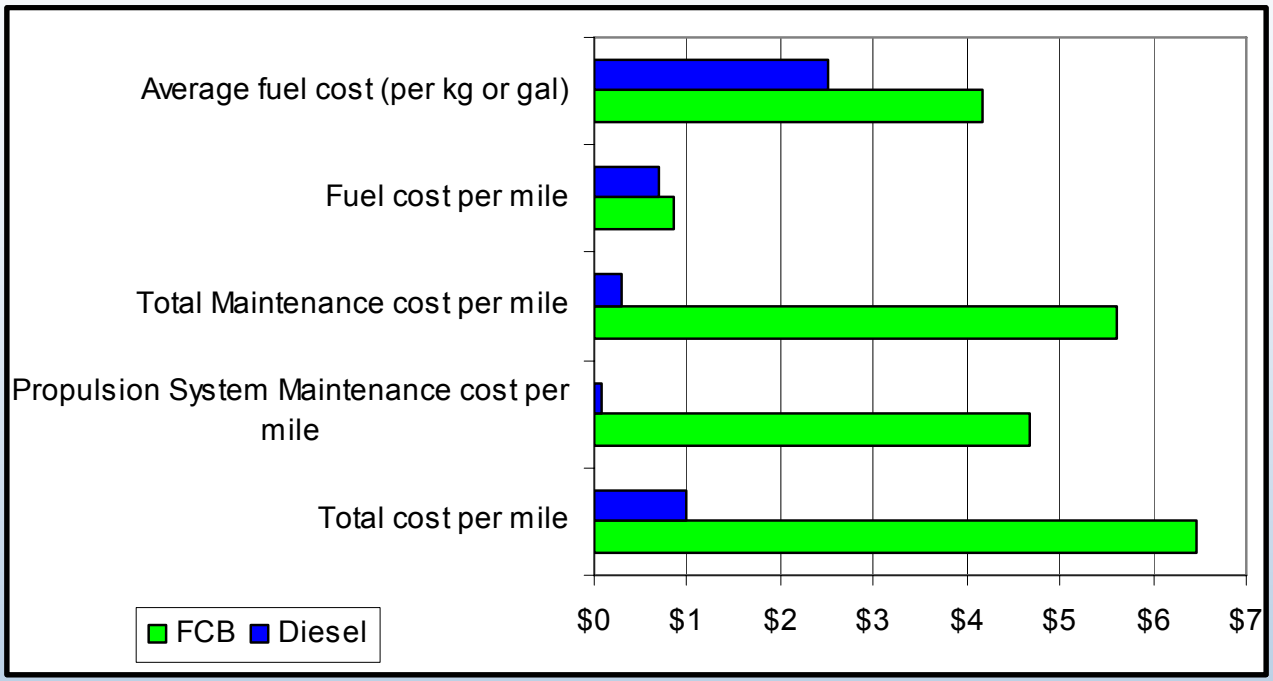




Fuel Cell Bus Diesel Bus

Fleet Data Summary: CTTRANSIT

Summary of Costs*



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Evaluation Status

- In-Progress
- 1st fleet operating in cold climate
- First data report summer 2008


CTTRANSIT Operates New England's First Fuel Cell Hybrid Bus

DOE Hydrogen Program

Fact Sheet Published 2/08
Available online at www.nrel.gov/hydrogen/pdfs/42407.pdf

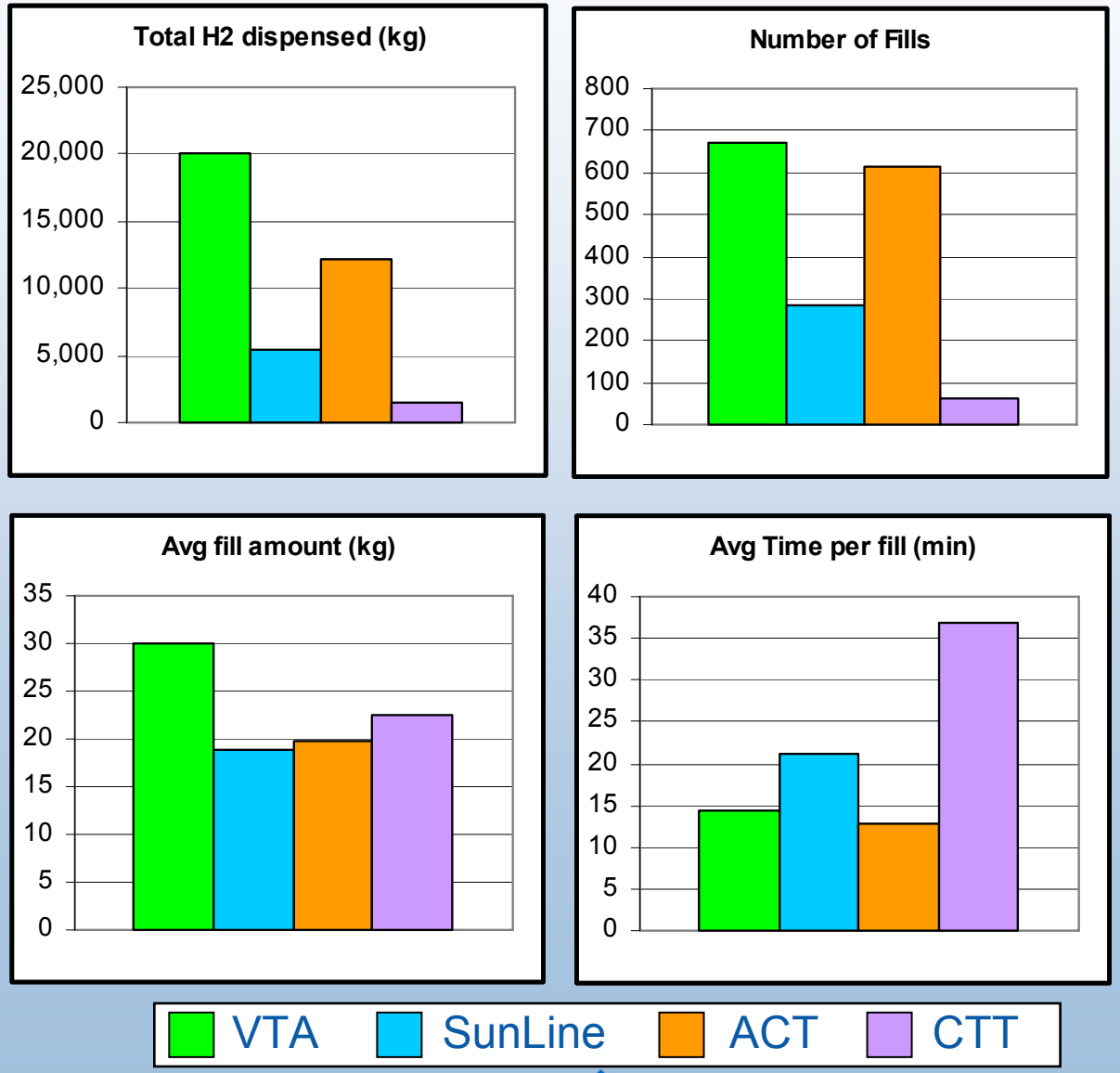
Infrastructure Data Summary

VTA
- Air Products
- Liquid H_2 storage
- Dispenses compressed H_2
- 32 months data

SunLine
- HyRadix
- Natural gas reformer
- 13 months data

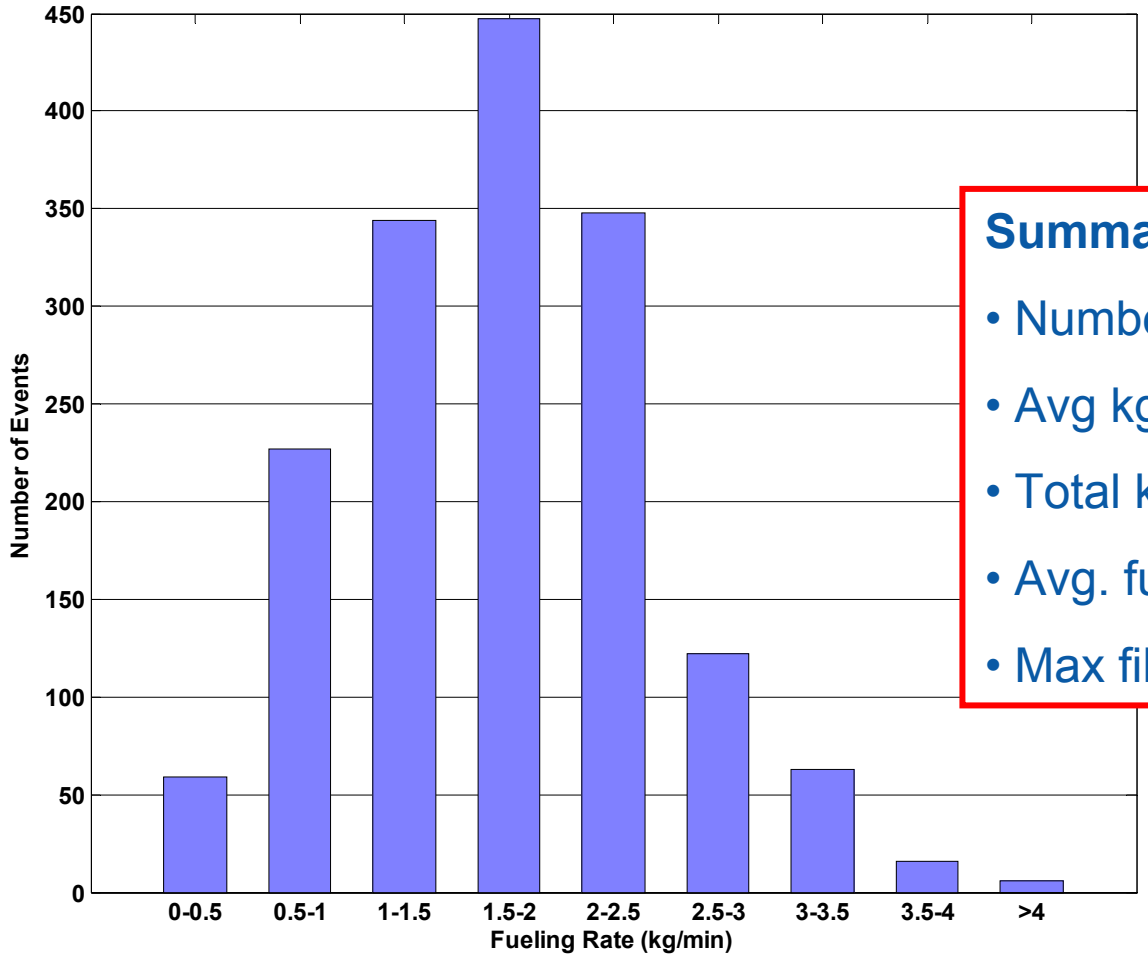
AC Transit
- Chevron
- Natural gas reformer
- 24 months data

CTTRANSIT
- UTC Power station
- Praxair
- Liquid H_2 storage
- Dispenses compressed H_2
- 9 months data



Infrastructure Data Summary

Fueling Rate Histogram – all fleets



Summary:

- Number of fueling events: 1,632
- Avg kg/fill: 23.9 kg
- Total kg dispensed: 39,077
- Avg. fueling rate: 1.5 kg/min
- Max fill rate: 4.67 kg/min

Future Work

- Remainder of FY 2008
  - Complete data analysis reports on AC Transit and SunLine
  - Initiate data collection on SunLine FCB with next generation fuel cell power system
  - Complete first data analysis report on **CT**TRANSIT
  - Complete update to FCB Summary and Status paper
- FY 2009
  - Complete analysis and final data report on Hickam
  - Complete update data analysis and report on **CT**TRANSIT and SunLine
  - Initiate data collection for second generation design FCBs at AC Transit and VTA
  - Coordinate data collection activities with FTA

Planned FCB Evaluations for DOE and FTA

Site/Locations	State	Eval. Funding	2007		2008				2009				2010			
			3	4	1	2	3	4	1	2	3	4	1	2	3	4
AC Transit /Oakland	CA	DOE Tech. Validation	HyRoad													
AC Transit /Oakland	CA								AC Transit CA ZEB 2009							
SunLine /Thousand Palms	CA		FCB/HHICE													
SunLine /Thousand Palms	CA				FCB Ext. Service											
SunLine /Thousand Palms	CA							Advanced FCB Project								
CTTRANSIT /Hartford	CT		CTTRANSIT FCB Demo													
Hickam AFB /Honolulu	HI		Air Force FCV Demo													
VTA /San Jose	CA								VTA CA ZEB 2009							
AC Transit /Oakland	CA	FTA National Fuel Cell Bus Program*		Accelerated Testing												
SunLine /Thousand Palms	CA							American FCB Demo								
CTTRANSIT /Hartford	CT							CT Hybrid FCB Demo								
Columbia /Site 2/ **CT**TRANSIT	SC/CT						Dual Variable Output Hybrid FCB									
Logan Airport /Boston	MA										MA H2 FCB Fleet					
NFTA /Buffalo	NY								Lightweight FCB Demo							
NFTA /Buffalo	NY									Hydroelectric H2 Powered FCB						
SFMTA /San Francisco	CA													FC APU Hybrid		

National Fuel Cell Bus Program

Demonstration sites are color coded by area:

- California
- New England
- Western NY
- Southeast
- Hawaii
- South

* Detailed data analysis funded by DOE

Summary

- Collected operational, performance, and cost data on 9 hydrogen fueled buses in real-world service at four transit agencies:
  - VTA: 17 months
  - SunLine: 27 months
  - AC Transit: 24 months
  - **CT**TRANSIT: 12 months
- Validated fuel cell bus performance characteristics equal to or better than diesel
  - Drivers report better acceleration and quiet operation
- Demonstrated that bus duty-cycle allows fast accumulation of miles/FC hours
  - Over 220,000 total miles and over 16,000 FC hours
- Collected performance and cost data on conventional technology to establish a baseline for tracking progress
  - Use of prototype FCBs is increasing, but still much less than standard buses
  - High cost for maintaining current generation prototype technology
- Transit agency staff are being trained to handle more of the maintenance repairs
  - For early demonstrations, all propulsion system related maintenance was handled by on-site manufacturer staff
  - Expect costs to rise

Summary (continued)

- Fuel cell bus use less than baseline
  - Beginning to increase as fleets accelerate testing
- Fuel economy
  - Highly dependent on duty-cycle
  - Results show need for hybridization
  - Improvement over conventional technology approaching 2X